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We treated 47 patients with a mean age of 57 years (22 to 88) who had a proximal humeral fracture in which there was a severe varus deformity, using a standard operative protocol of anatomical reduction, fixation with a locking plate and supplementation by structural allografts in unstable fractures. The functional and radiological outcomes were reviewed.

At two years after operation the median Constant score was 86 points and the median Disabilities of the Arm, Shoulder and Hand score 17 points. Seven of the patients underwent further surgery, two for failure of fixation, three for dysfunction of the rotator cuff, and two for shoulder stiffness. The two cases of failure of fixation were attributable to violation of the operative protocol. In the 46 patients who retained their humeral head, all the fractures healed within the first year, with no sign of collapse or narrowing of the joint space. Longer follow-up will be required to confirm whether these initially satisfactory results are maintained.

Fractures of the proximal humerus with varus deformity are a small but important subgroup which comprise over 10% of proximal humeral fractures.[1] These injuries are difficult to define and, depending on the displacement and involvement of the articular surface and tuberosity, can be classified variously in the Orthopaedic Trauma Association system,[2,3] as subtypes 11-A2.2, C1.2 or C2.2, and in the Neer classification,[4] as two-, three- or four-part fractures.

Conservative treatment of these injuries produces satisfactory functional results in most patients who are either elderly or who have a less severe varus deformity.[5] However, it is our experience that the functional outcome after conservative treatment is less predictable in younger patients and when the degree of angulation is more severe (head-shaft inclination angle of < 100°). This may be because of the reduction of the articular arc available for glenohumeral movement and dysfunction of the rotator cuff from the altered orientation of its attachments to the tuberosities. Secondary displacement of the shaft relative to the head may also result in nonunion.

These fractures pose unique problems in reconstruction, since disruption of the buttress of the posteromedial calcar predisposes them to failure of fixation after open reduction and fixation with a plate alone.[6-12] Despite this, we have adopted a policy of operative treatment for all patients with more severe varus deformity. We now describe the anatomical features of this injury and an operative technique for its reduction and internal fixation (ORIF) and evaluate prospectively the functional and radiological outcomes from this treatment in a consecutive series of patients.

Patients and Methods

Between March 2002 and February 2007, we studied a consecutive series of patients with proximal humeral fractures in which there was a varus deformity of the humeral head. Only acute fractures in medically-fit and locally-resident patients and those which were markedly-angulated with a head-shaft inclination angle of ≤ 100° were included.

The mean age of the 47 patients (21 men, 26 women) undergoing operation was 57 years (22 to 88). The fractures had been sustained in simple falls in 27 patients, in falls from a height or downstairs in 12, from contact-sports injuries in five and in road-traffic accidents in three. Fractures in men under 65 years of age were most commonly produced by high-energy injuries and in patients over 65 years of age by low-energy falls. Two patients had temporary palsy of the axillary nerve, two had an associated fracture of the distal radius and one a haemothorax and an ipsilateral femoral fracture.

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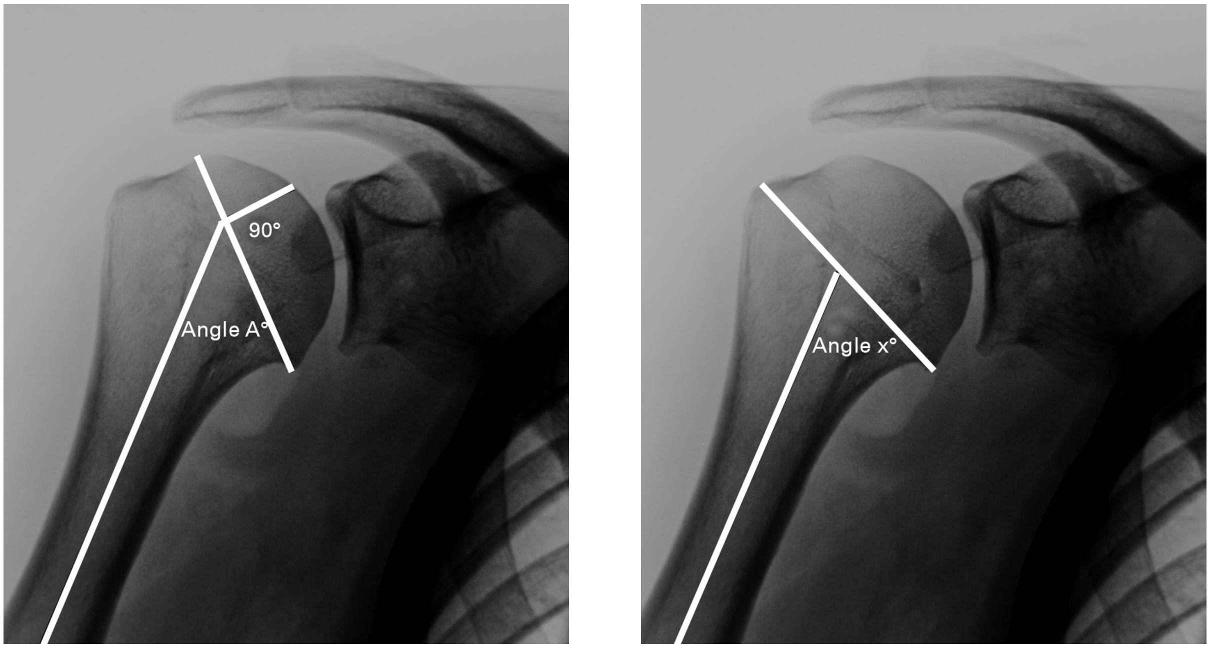

Fig. 1a

Fig. 1b

Radiographs of the two techniques used to measure the varus deformity showing a) that of Boileau and Walch[13] and Iannotti et al,[14] and b) that of Court-Brown and McQueen.[5]

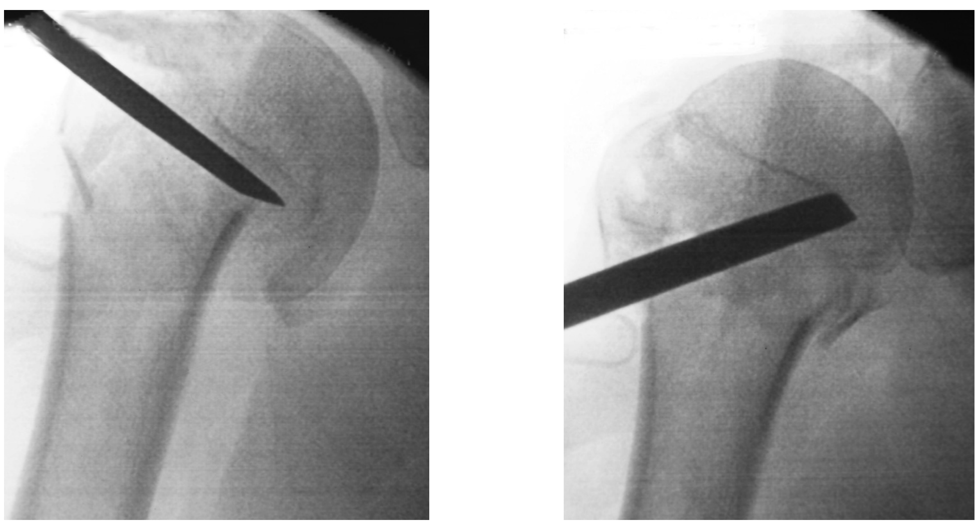

Fig. 2a

Fig. 2b

Intra-operative radiographs of the technique used to correct the varus deformity and elevate the head segment from its posteroinferiorly subluxed position showing a) an osteotome is inserted within the central section of the humeral head and b) using the osteotome as a joystick, the head fragment is then elevated back into a reduced position.

On the initial pre-operative anteroposterior (AP) radiograph we measured the varus angulation using two previously-described techniques. The first (Fig. 1a) assessed the inclination of the anatomical neck of the humerus relative to the long axis of the diaphysis (head-shaft inclination angle).[13,14] In the second (Fib. 1b), the inclination of a line joining the tip of the greater tuberosity to the inferior articular edge of the humeral head was measured, relative to a line along the long axis of the diaphysis.[5] The increased varus angulation was calculated by subtracting this value from the 'normal' 50° for this measurement. We also assessed radiologically the number of fracture fragments, their configuration and the pattern of displacement of the shaft relative to the head. Three-dimensional CT was performed on all frac-

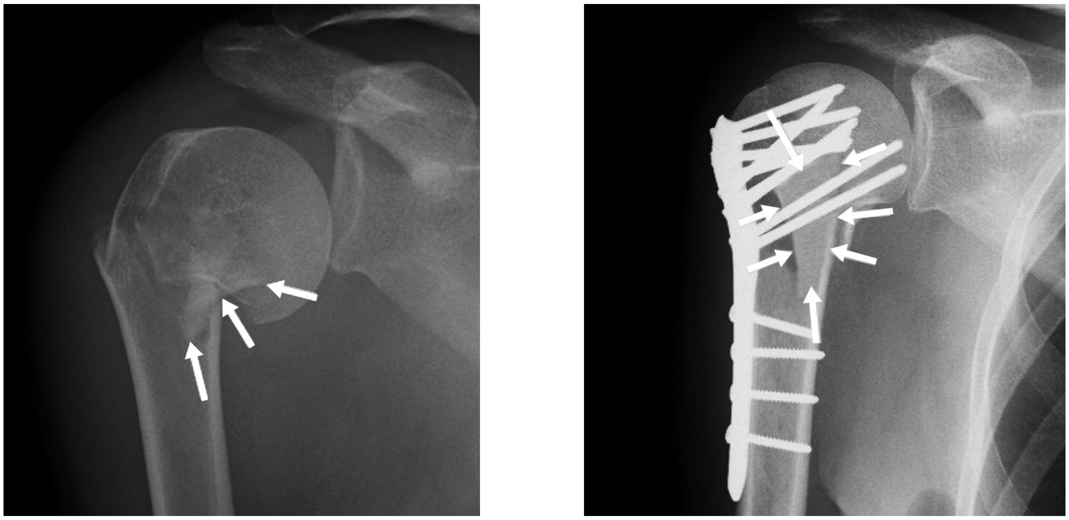

Fig. 3a Fig. 3b

Anteroposterior radiographs of a 56-year-old man who sustained a varus fracture with inferior subluxation of the humeral head after a fall down stairs showing a) comminution of the medial buttress (arrowed) and b) after reduction of the head, the medial buttress was supported by a sculpted allograft from the femoral head (arrowed) and two lower quadrant humeral head screws were inserted through the locking plate.

tures after May 2004. From a combination of the radiological and operative findings the anatomical features of the fractures were described and classified.[4]

Operative technique. All the operations were performed by the senior author (CMR) at a mean of three days after injury (0 to 10). Under general anaesthesia, with the patient in the 'beach-chair' position, an extended deltoid-splitting approach was used through a superior 'shoulder-strap' incision.[15] The anterior terminal branch of the axillary nerve was identified and protected where it crossed the split of the deltoid. The superior window in the deltoid above the nerve was used for the reduction of the fracture, bone grafting and plate fixation into the humeral head. The lower deltoid window below the nerve was used for the insertion of the lower screws into the plate. We aimed to reduce all the components of the fracture anatomically. The deformity was corrected using an osteotome or Steinmann pin inserted into the humeral head and used as a joystick (Fig. 2). Provisional fixation was achieved by temporary Kirschner wires.

Posteromedial comminution in the region of the calcar was encountered in 21 patients. This was not amenable to fixation by lag screws and, in these patients, a sculpted triangular bone allograft from the femoral head was used to restore bony continuity across the medial column (Fig. 3). This was stabilised by impaling the distal apex of the graft into the medullary canal.

If one or both tuberosities were fractured they were reattached to each other using three or four interosseous non-absorbable sutures once provisional reduction of the humeral head had been achieved. Those fragments of the tuberosities which had considerable marginal portions of the articular surface attached were reduced through a rotator interval arthrotomy and fixed using 3.5 mm cannulated screws (Synthes, Welwyn Garden City, United Kingdom) or Acutrak screws (Acumed, Andover, United Kingdom). Definitive fixation was achieved using a proximal humeral locking plate (Philos Plate; Synthes). We aimed to insert the lower two locking head screws across the calcar and into the inferior quadrant of the humeral head to protect against re-displacement from the disruption of the medial calcar support.

All the patients were rested in a shoulder sling for four weeks post-operatively. Pendular exercises and elbow movement were allowed during this time. Isometric exercises of the rotator cuff and graduated, active range-of-movement exercises were commenced after removal of the sling.

Outcome assessment. The principal outcome measures were functional and radiological, and the prevalence of fracture-related complications within the first two years post-operatively was determined. All the patients were reviewed prospectively by a research assistant at one and six weeks, three and six months and one and two years after their injury. At each visit the patient underwent assessment using the Short Form-36 (SF-36) general health questionnaire,[16,17] the upper limb-specific disabilities of the arm, shoulder and hand (DASH) questionnaire[18] and the shoulder-specific score of Constant and Murley.[19] The employment status of the patient was recorded at each appointment. Specific tests for weakness of the rotator cuff, impingement and dysfunction of the biceps tendon were also performed at each visit from three months onwards. AP and axial radiographs were also reviewed at each appointment.

Statistical analysis. The SF-36 scores were individually compared with age- and sex-matched control values for the normal population using the Mann-Whitney U test. The

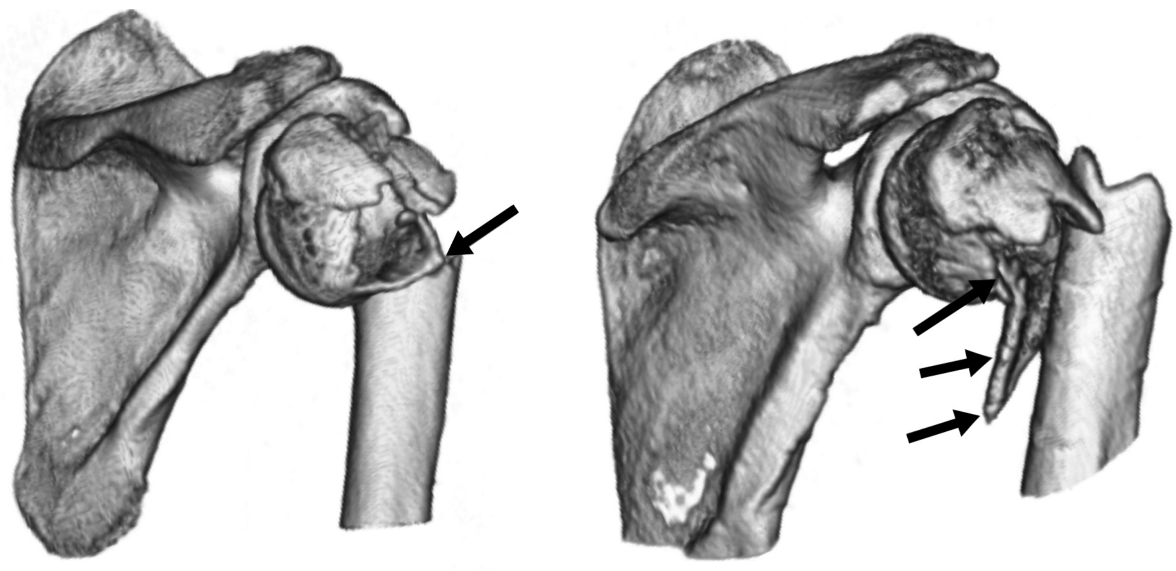

Fig. 4a

Fig. 4b

Three-dimensional CT scans showing a) a fracture in which the metaphyseal spike remained intact and attached to the humeral head (arrowed) and b) fracture of the medial buttress with a solitary metaphyseal fragment (arrowed) which was separated from both the humeral head and the proximal diaphysis.

time-trend changes in functional outcome scores were examined using the Wilcoxon matched-pairs test. A p-value ≤ 0.05 was considered to be significant.

Results

The mean pre-operative head-shaft inclination angle (Fig. 1a) was 68° (20° to 100°, 95% confidence interval (CI) 61 to 75). In 24 patients (51.1%) it was between 75° and 100°, in 11 (23.4%) between 50° and 74° and in 12 (25.5%) ≤ 49°. The mean increased varus angulation (Fig. 1b) was 61° (30° to 110°, 95% CI 55 to 68). In 16 patients (34.6%) it was between 30° and 49°, in 13 (27.7%) between 50° and 69° and in 18 (38.3%) ≥ 70°. In addition to the varus deformity, the humeral head was typically flexed and internally rotated. It appeared to be subluxed posteroinferiorly because of its varus deformity, but frank dislocation was not encountered.

In 26 patients, there was cortical continuity with a single posteromedial bone spike attached to the head (Fig. 4a). Bone grafting was not performed in these cases. Femoral allograft was used in 21 cases where there was posteromedial comminution (Fig. 4b).

In 27 patients neither tuberosity was involved (Neer two-part fractures), 12 had three-part fractures of the greater tuberosity (six with articular involvement), and eight had four-part fractures (five with articular involvement).

Complications. There were no deep wound infections or any further neurological deficits. Seven of the 47 patients underwent further surgery. Two older women developed failure of fixation with recurrent varus deformity within two weeks of the operation. The initial head-shaft inclination angles were severe in both, namely 30° and 35°. In both patients, the varus deformity was not fully corrected intra-operatively and the post-operative head-shaft angles were 115° and 120°. Both fractures had instability of the medial buttress with extensive comminution and structural allograft had been used in both. One had malposition of the plate and low posteroinferior calcar screws had not been inserted into the lower quadrant of the head. None of the other fractures had varus malreduction (head-shaft inclination < 130°) and calcar screws were inserted in all other cases. The two patients with failed fixation had revision surgery. One had revision of the fixation and one had a replacement arthroplasty. Both subsequently developed stiff shoulders but were free from pain.

Two patients developed symptomatic subacromial impingement and underwent open acromioplasty and removal of the metal. Another developed progressive osteolysis of the greater tuberosity and had painless loss of active abduction, but with a full range of passive movement. MRI showed an intact rotator cuff, but patulous tendons of supraspinatus and infraspinatus with atrophy which was confirmed by arthroscopy. He underwent removal of the metal and subacromial decompression. His symptoms improved, but he had persistent pain-free restriction of active movement and weakness of the rotator cuff at the final follow-up.

Two patients developed post-traumatic stiffness in a capsular pattern which failed to respond to intensive stretching exercises. Both were treated successfully by arthroscopic soft-tissue excision of scar tissue in the rotator interval, circumferential capsular release of the glenohumeral joint, excision of subacromial adhesions and acromioplasty.

Radiological outcome. The mean post-operative head-shaft inclination angle (Fig. 1a) was 136° (115° to 145°), with a mean overcorrection of the pre-operative increased varus

Table I. Median (IQR) Constant and Disabilities of the Arm, shoulder and hand (DASH) scores and mean range of movement in the 47 patients with varus fractures at the four assessment points after open reduction and internal fixation (ORIF)

		Time of assessment (number of patients assessed)			
Assessment parameter	**Subgroups**	**3 mths (n = 43)**	**6 mths (n = 42)**	**1 yr (n = 43)**	**2 yrs (n = 45)**
Constant score	Two-part fractures (n = 27)	44 (34 to 56)	63 (56 to 81)	80 (72 to 90)	88 (76 to 92)
	Three/four-part fractures (n = 20)	40 (35 to 44)	70 (59 to 76)	78 (75 to 88)	80 (77 to 92)
	Fractures treated by ORIF only (n = 26)	42 (36 to 55)	61 (55 to 79)	78 (58 to 90)	89 (83 to 93)
	Fractures requiring ORIF and bone grafting (n = 21)	44 (33 to 55)	74 (64 to 78)	82 (78 to 88)	84 (74 to 90)
	Overall for whole population assessed (n = 47)	44 (34 to 55)	67 (56 to 79)	80 (75 to 89)	86 (77 to 92)
DASH score	Two-part fractures (n = 27)	41 (31 to 53)	31 (13 to 35)	20 (11 to 24)	13 (5 to 20)
	Three/four-part fractures (n = 20)	48 (37 to 56)	35 (16 to 38)	27 (17 to 34)	19 (14 to 23)
	Fractures treated by ORIF only (n = 26)	47 (35 to 55)	35 (13 to 41)	21 (12 to 33)	16 (12 to 23)
	Fractures requiring ORIF and bone grafting (n = 21)	46 (26 to 55)	28 (17 to 35)	20 (16 to 34)	19 (7 to 23)
	Overall for whole population assessed (n = 47)	47 (31 to 56)	34 (15 to 38)	21 (14 to 34)	17 (12 to 23)
Range of movement in degrees (95% CI*)	Forward flexion	81 (72 to 90)	135 (125 to 144)	156 (147 to 164)	159 (151 to 168)
	Abduction	70 (60 to 80)	129 (118 to 141)	152 (143 to 162)	153 (141 to 165)
	Internal rotation	76 (68 to 83)	83 (79 to 87)	88 (86 to 89)	88 (86 to 91)
	External rotation	19 (13 to 24)	41 (33 to 50)	51 (43 to 58)	53 (45 to 61)

* CI, confidence interval

angulation (Fig. 1b) of -6° (-15° to +15°). With the exception of the two patients with acute failure of fixation there was little change in the head-shaft angle during follow-up. At two years, the final head-shaft inclination angle in the 46 patients who retained their humeral heads was 137° (130° to 145°), with residual overcorrection of the varus angulation of -4° (-10° to +2°). All these 46 patients had union by six months after injury. Five patients (three men, two women, mean age 59 years) with three two-part fractures and two three-part fractures, had asymptomatic patchy osteolytic and osteosclerotic changes in the humeral head without structural collapse or joint-space narrowing. There was no radiological abnormality in the humeral heads of the remainder of the cohort.

Functional outcome. All patients attended for their first review, but some missed one or more subsequent appointments (Table I). The two who defaulted from the follow-up at two years had been reviewed at one year. The two patients with a pre-operative axillary nerve palsy had full motor and sensory recovery within six weeks of injury.

The median Constant and DASH scores improved significantly throughout the first year (Wilcoxon matched-pairs test, $p < 0.05$ for each visit, Table I) after which there was no significant further improvement. The median Constant score was 86 points at two years (interquartile range (IQR) 77 to 92) and the median DASH score was 17 points at two years (IQR 12 to 23). The sequential changes in the two scores are shown in Table I. This also shows a subgroup analysis of two- *versus* three- and four-part fractures and fractures in which ORIF alone was performed *versus* those in which allograft support was used. At two years, there was no difference in any of the eight components of the SF-36 when compared with an age and gender-matched control group. The sequential change in the range of movement over the two years is shown in Table I. The Constant scores and range of abduction and external rotation in patients with two-part fractures were significantly better than those with three- and four-part fractures ($p < 0.05$ in all cases). Although the median functional scores were better in those patients who did not require allograft, compared with those in which it was used, this difference did not reach statistical significance. Similar non-statistically significant trends were also noted when patients under or over 65 years old were compared and also when those with fractures with more severe or less severe initial varus angulation were compared. The two patients who had failed primary fixation and required early revision, and those with resorption of the tuberosity, were persistent outliers in terms of poorer functional scores and range of movement. None of the other patients had evidence of weakness or impingement of the rotator cuff, glenohumeral instability, or dysfunction of the biceps tendon at their final follow-up.

By six months after injury, 16 of the 20 patients who had previously been employed in sedentary jobs had returned to work, and 18 had returned by one year. The two remaining patients had lost their jobs because of their enforced absence. Both were subsequently re-employed in sedentary posts at 14 and 16 months after injury. Of the 11 patients previously employed in manual work, seven returned to their previous work, three changed to more sedentary posts and one took voluntary retirement. The remaining 16 were either unemployed or retired from active work at the time of injury.

Discussion

Varus-angulated fractures are an important, but poorly defined subgroup of fractures of the proximal humerus[5,20] and, although some of the anatomical features have been described previously, our study is the first to examine these in a larger series. These injuries have a spectrum of severity, with considerable variation in the degree of varus deformity, displacement of the humeral head and involvement of the tuberosities. The severity of the varus deformity can be underestimated on conventional radiographs if they are not taken in the plane of maximal deformity. Three-dimensional CT reconstructions give useful additional information about the extent of involvement of the posteromedial buttress, the location and extent of secondary fracture lines in the tuberosities and the presence of marginal fragments attached to them. This assists in pre-operative planning.

Most of our patients regained nearly normal levels of function, as reflected in their range of movement and functional scores. The reasons for these satisfactory results were probably multifactorial. The patients with these injuries were younger than the general population who sustain proximal humeral fractures and most fractures were two-part. Later problems with the rotator cuff were therefore unusual. We attempted to reduce and fix all the fractures anatomically and problems related to malunion and non-union were thus reduced.

Our study is the first to describe the outcome of a fixed protocol of ORIF using a locking plate for this specific injury pattern. We aimed to restore stability to the medial buttress using screws in the lower quadrant of the head, supplemented by allograft bone when one or more separate comminuted fragments prevented restoration of cortical continuity across the medial buttress. Both the acute failures had at least one violation of the treatment protocol. In the fractures which were reduced without residual varus deformity and had screws positioned within the lower quadrant of the humeral head, there were no early fixation failures.

The treatment of these injuries is technically challenging when there is disruption of the medial cortical buttress. Traditional plate fixation functions as a lateral tension band but, in the presence of medial instability there is a high risk of failure of this form of fixation alone.[6-12] Recent studies suggest that avoidance of residual varus deformity,[6-12] oblique insertion of plate screws within the lower quadrant,[12] medialisation and impaction of the fragment of the humeral shaft into the head,[8,12] and the use of allografts[21] may restore stability to the medial buttress and help to prevent failure of fixation. We do not feel that the use of allograft is indicated in fractures with an intact posteromedial calcar spike in which full bony congruity can be restored across the medial buttress.

Despite our satisfactory overall results, further surgery was required in seven patients, although five of these underwent treatment for problems related to stiffness or impingement of the rotator cuff. It is our experience that soft-tissue capsular releases are more effective in the presence of an anatomical reconstruction, rather than complex malunion after non-operative treatment. Good functional outcomes were achieved in most of these patients and, in general, most who were in employment before their injury were able to return to their previous occupations.

All except one of the fractures united without evidence of osteonecrosis. Since the primary fracture line in varus fractures is often below the line of capsular reflection, branches of the posterior circumflex artery are preserved and may be a source of blood supply to the humeral head, irrespective of whether the tuberosities are involved. Fractures with an appreciable intact spike of bone extending into the medial metaphysis have been shown to have a higher rate of perfusion at operation and this may explain our low rate of osteonecrosis.[22]

Direct comparison of our results with other studies was not possible since there was no comparable series, Minimally displaced varus fractures can be treated conservatively with the expectation of uncomplicated healing and a satisfactory functional outcome.[5,23] However, it is our experience that when the varus deformity is more severe, the results of conservative treatment are more unpredictable and the deformity tends to worsen and predipose to nonunion. In a previous study of these fractures, although there was a correlation between increasing varus angulation and poor function at one year, multiple regression analysis did not show a statistically significant association between these variables.[5] However, only 6% of the fractures in this series had a severe deformity of > 29° of increased varus, whereas 40% had a deformity of < 10°.[5] The degree of deformity in our series was greater, with a mean head-shaft inclination angle of 68° with all patients having an increased varus deformity of > 30°. Our patients therefore correspond to the minority of 6% of more severely displaced fractures in the previous study. Nevertheless, the functional results in our series were comparable with those achieved for less severely angulated varus fractures in the previous study of conservative treatment.[5]

Our study was from a single unit and our results cannot be extrapolated to other centres without a specialist interest. We considered only more severely angulated fractures in medically-fit patients, and the threshold of angulation at which the benefits of operative treatment are outweighed by the potential complications cannot be defined accurately. However, it is our practice to offer surgery to all medically-fit patients with head-shaft inclination angles of ≤ 100°.

Another weakness of our study was that it provided only case-series evidence of the value of open surgery. There was no control group treated conservatively or by other techniques, such as percutaneous fixation, intramedullary nailing or arthroplasty, with which to compare our results. However, our inclusion and exclusion criteria dictated that we were treating a relatively small subgroup of patients with more severe fracture configurations. Given the satisfactory outcome, it would require a large clinical trial to power a study adequately in order to evaluate whether alternative techniques would give a better functional outcome.

We feel that our results support the routine use of primary ORIF in medically-fit patients with severely displaced varus fractures with a head-shaft inclination angle of < 100°. Longer follow-up is required to assess whether they develop osteonecrosis or osteoarthritis. However, the relatively high mortality in the more elderly patients with osteoporosis may predetermine that many will not survive long enough for this to become clinically significant.

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